MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 1, 2015/2016**

## ETM3136 – DIGITAL COMMUNICATIONS

(TE)

6 OCTOBER 2015
09:00 a.m – 11:00 a.m
(2 Hours)

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**INSTRUCTION TO STUDENTS**

1. This question paper consists of 7 pages with **4** Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

## Question 1

(a) Explain with an aid of useful graph the intersymbol interference (ISI), the causes for ISI, and list the two major ways to mitigate the detrimental effect of ISI.

[8 marks]

(b) A voice band telephone channel passes the frequencies in the band from 200Hz to 2200Hz. It's desired to design a modem that transmit at a symbol rate of 2100 symbols/s, with the objective of achieving 10000bits/s.

(i) Design a system with an appropriate modulation scheme, carrier frequency, and the roll-off factor of a pulse with a raised cosine spectrum that utilizes the entire frequency band. [7 marks]

(ii) Sketch the spectrum of the transmitted signal pulse and indicate the important frequencies. [3 marks]

(c) State the two requirements which must be satisfied for no distortion at the output of a linear time invariant system. The amplitude response and phase response of a communication channel are shown in Figure Q1. Analyze whether the channel will provide distortionless transmission or not. Justify your answer.

[7 marks]

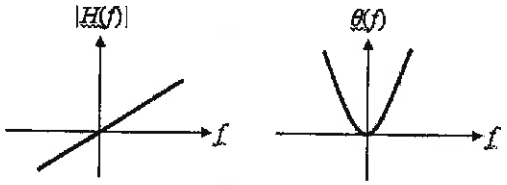


Figure Q1

**Continued...**

## Question 2

(a) An ideal lowpass filter used to reconstruct the following signal

$$x(t) = 10\cos(600\pi t)\cos^2(2400\pi t)$$

The signal is sampled at 6000 samples per second.

(i) Determine the range of permissible cutoff frequencies of the lowpass filter, and find the minimum allowable sampling frequency. [4 marks]

(ii) Consider the above signal is an input signal to the quantizer for PCM, find the signal to noise ratio (SNR) in dB at the output of the quantizer. [6 marks]

(iii) Determine the minimum value of number of bits ($n$) such that the output SNR is no less than 39.5dB. [1 marks]

(b) A voice signal (300 to 3300 Hz) is digitized such that the quantization distortion $\leq \pm 0.1\%$ of the peak to peak signal voltage. Assume a sampling rate 21% above the Nyquist rate, and a raised-cosine pulse with a 50% roll-off factor. Find the minimum system bandwidth that avoids ISI. [6 marks]

(c) Consider the configuration of an analog-to-digital converter depicted in figure Q2A. At the input of the analog-to-digital converter, the desired signal $s(t)$ is disturbed by an interfering signal $i(t)$. The frequency spectra of $S(f)$ and $I(f)$ are shown in figure Q2B.

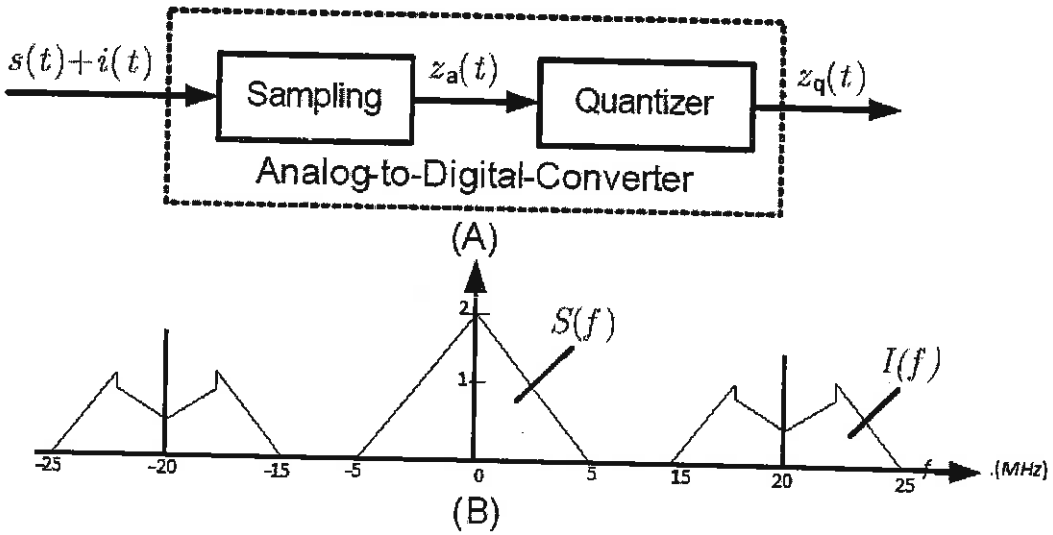


Figure Q2

(i) Draw the frequency spectrum $Z_a(f)$ of the signal $z_a(t)$ resulting after sampling within the range $-25\text{MHz} \leq f \leq 25\text{MHz}$ assuming a sampling frequency of $f_a$ = 20MHz. Label the axis. [4 marks]

(ii) Explain two technically different solutions that nevertheless allow for recovering the desired signal $s(t)$ from the sampled signal $z_a(t)$ without errors. Give reasons for both solutions. Draw the frequency spectrum $Z_a(f)$ of the signal $z_a(t)$ within the range $-35\text{MHz} \leq f \leq 35\text{MHz}$ for both solutions. [4 marks]

**Continued...**

## Question 3

(a) A baseband digital transmission system that sends $\pm A$ valued rectangular pulses through a channel at a data rate of 10kbps is to achieve an error probability of $10^{-6}$. If the noise power spectral density is $N_0=10^{-7}$ Watt/Hz.

(i) What is the required value of $A$? [6 marks]

(ii) What is the minimum transmitted power? [1 marks]

(iii) Consider the system makes errors at the average rate of 100 errors per day, will the received power found in (ii) be adequate to maintain the error probability. [4 marks]

(b) State and explain the difference between the two kinds of frequency hopping, and write the relationships between the chip rate, symbol rate, bit rate, and hopping rate. [8 marks]

(c) Assuming that each user in a cellular system makes one 5 minutes call every 2 hours, how many users can be supported for 0.5% probability of blocking in an Erlang B system for a number of trunked channels equal to 25. [6 marks]

**Continued...**

## Question 4

(a) 18 kHz baseband frequency of analog signal is converted to digital using analog to digital convertor, which has 4 bit encoder. Assume a sampling rate is 25% above the Nyquist rate. After encoding, the stream of bits was spread by pseudo noise (PN) sequence, where the chip rate is 1Gbps. The transmission takes place over an ideal bandlimited additive white Gaussian noise (AWGN) channel and the power spectral density of the noise is $N_0 = 1\times 10^{-10}$ W/Hz. Binary PSK is used to digitally modulate the data.

(i) What is the jamming margin against a continuous tone jammer if the desired error probability is $10^{-9}$? [10 marks]

(ii) What is the minimum amount of power needed at the transmitter in order to maintain a bit error probability of $P_B=10^{-9}$? Assume that, the data is transmitted along a cable that attenuates the signal power by 25dB.

[2 marks]

(b)

(i) State the motivations towards using multi-stage switching instead of single-stage switching. [5 marks]

(ii) Consider three-stage switching structure that accommodates $N = 16$ input and 16 output terminals. Compare the number of crosspoints required by a nonblocking switch with $n = 16$, $n = 8$, $n = 4$, and $n = 2$. [8 marks]

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# Appendix I

## Tabulated values of Q-function

**The Q Function (Gaussian Distribution with $\mu = 0$ and $\sigma = 1$)**

$$Q(a) = \int_a^\infty \frac{1}{\sqrt{2\pi}} e^{\frac{-x^2}{2}} dx \qquad Q(a) \cong \frac{1}{a\sqrt{2\pi}} e^{\frac{-a^2}{2}} \text{ for } a \geq 3$$

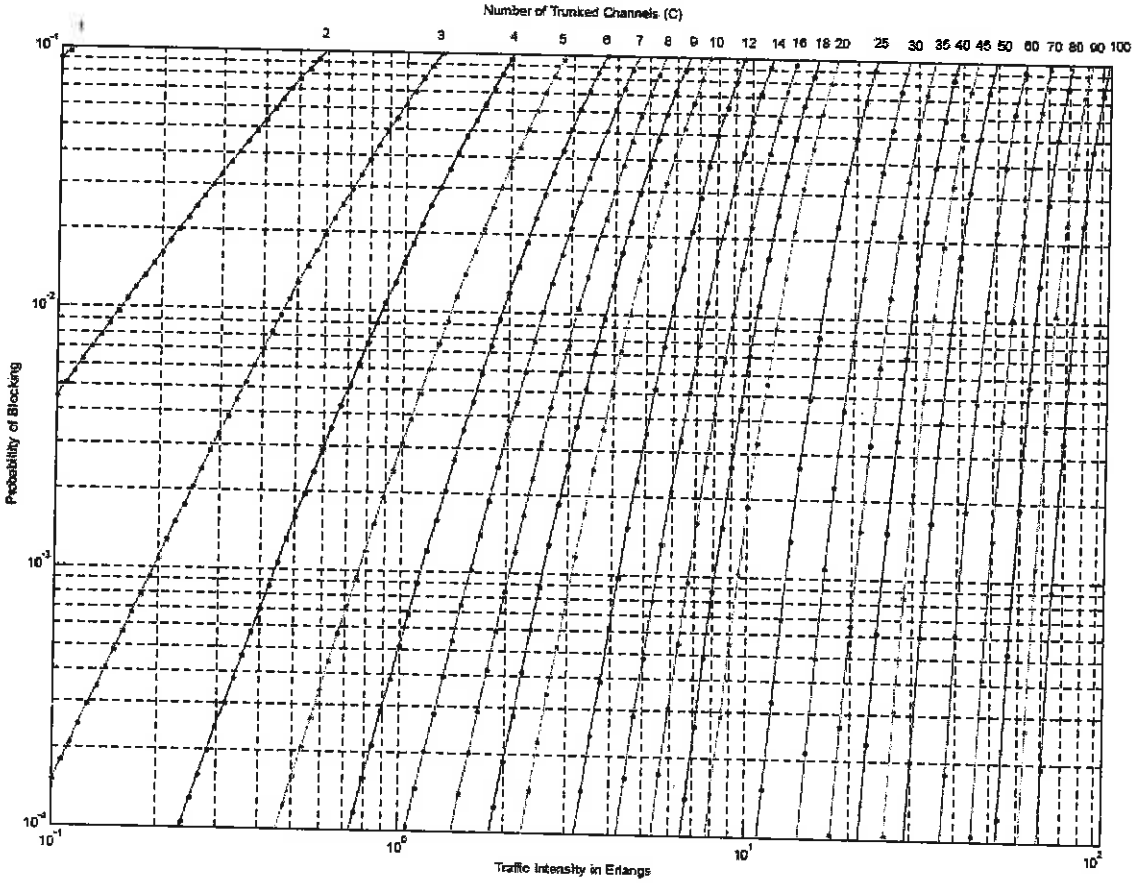
| | 3rd Significant Digit | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $a$ | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
| 0.0 | 0.5000 | 0.4960 | 0.4920 | 0.4880 | 0.4840 | 0.4801 | 0.4761 | 0.4721 | 0.4681 | 0.4641 |
| 0.1 | 0.4602 | 0.4562 | 0.4522 | 0.4483 | 0.4443 | 0.4404 | 0.4364 | 0.4325 | 0.4286 | 0.4247 |
| 0.2 | 0.4207 | 0.4168 | 0.4129 | 0.4090 | 0.4052 | 0.4013 | 0.3974 | 0.3936 | 0.3897 | 0.3859 |
| 0.3 | 0.3821 | 0.3783 | 0.3745 | 0.3707 | 0.3669 | 0.3632 | 0.3594 | 0.3557 | 0.3520 | 0.3483 |
| 0.4 | 0.3446 | 0.3409 | 0.3372 | 0.3336 | 0.3300 | 0.3264 | 0.3228 | 0.3192 | 0.3156 | 0.3121 |
| 0.5 | 0.3085 | 0.3050 | 0.3015 | 0.2981 | 0.2946 | 0.2912 | 0.2877 | 0.2843 | 0.2810 | 0.2776 |
| 0.6 | 0.2743 | 0.2709 | 0.2676 | 0.2643 | 0.2611 | 0.2578 | 0.2546 | 0.2514 | 0.2483 | 0.2451 |
| 0.7 | 0.2420 | 0.2389 | 0.2358 | 0.2327 | 0.2297 | 0.2266 | 0.2236 | 0.2207 | 0.2177 | 0.2148 |
| 0.8 | 0.2119 | 0.2090 | 0.2061 | 0.2033 | 0.2005 | 0.1977 | 0.1949 | 0.1922 | 0.1894 | 0.1867 |
| 0.9 | 0.1841 | 0.1814 | 0.1788 | 0.1762 | 0.1736 | 0.1711 | 0.1685 | 0.1660 | 0.1635 | 0.1611 |
| 1.0 | 0.1587 | 0.1562 | 0.1539 | 0.1515 | 0.1492 | 0.1469 | 0.1446 | 0.1423 | 0.1401 | 0.1379 |
| 1.1 | 0.1357 | 0.1335 | 0.1314 | 0.1292 | 0.1271 | 0.1251 | 0.1230 | 0.1210 | 0.1190 | 0.1170 |
| 1.2 | 0.1151 | 0.1131 | 0.1112 | 0.1094 | 0.1075 | 0.1057 | 0.1038 | 0.1020 | 0.1003 | 0.0985 |
| 1.3 | 0.0968 | 0.0951 | 0.0934 | 0.0918 | 0.0901 | 0.0885 | 0.0869 | 0.0853 | 0.0838 | 0.0823 |
| 1.4 | 0.0808 | 0.0793 | 0.0778 | 0.0764 | 0.0749 | 0.0735 | 0.0721 | 0.0708 | 0.0694 | 0.0681 |
| 1.5 | 0.0668 | 0.0655 | 0.0643 | 0.0630 | 0.0618 | 0.0606 | 0.0594 | 0.0582 | 0.0571 | 0.0559 |
| 1.6 | 0.0548 | 0.0537 | 0.0526 | 0.0516 | 0.0505 | 0.0495 | 0.0485 | 0.0475 | 0.0465 | 0.0455 |
| 1.7 | 0.0446 | 0.0436 | 0.0427 | 0.0418 | 0.0409 | 0.0401 | 0.0392 | 0.0384 | 0.0375 | 0.0367 |
| 1.8 | 0.0359 | 0.0351 | 0.0344 | 0.0336 | 0.0329 | 0.0322 | 0.0314 | 0.0307 | 0.0301 | 0.0294 |
| 1.9 | 0.0287 | 0.0281 | 0.0274 | 0.0268 | 0.0262 | 0.0256 | 0.0250 | 0.0244 | 0.0239 | 0.0233 |
| 2.0 | 0.0228 | 0.0222 | 0.0217 | 0.0212 | 0.0207 | 0.0202 | 0.0197 | 0.0192 | 0.0188 | 0.0183 |
| 2.1 | 0.0179 | 0.0174 | 0.0170 | 0.0166 | 0.0162 | 0.0158 | 0.0154 | 0.0150 | 0.0146 | 0.0143 |
| 2.2 | 0.0139 | 0.0136 | 0.0132 | 0.0129 | 0.0125 | 0.0122 | 0.0119 | 0.0116 | 0.0113 | 0.0110 |
| 2.3 | 0.0107 | 0.0104 | 0.0102 | 0.0099 | 0.0096 | 0.0094 | 0.0091 | 0.0089 | 0.0087 | 0.0084 |
| 2.4 | 0.0082 | 0.0080 | 0.0078 | 0.0075 | 0.0073 | 0.0071 | 0.0069 | 0.0068 | 0.0066 | 0.0064 |
| 2.5 | 0.0062 | 0.0060 | 0.0059 | 0.0057 | 0.0055 | 0.0054 | 0.0052 | 0.0051 | 0.0049 | 0.0048 |
| 2.6 | 0.0047 | 0.0045 | 0.0044 | 0.0043 | 0.0041 | 0.0040 | 0.0039 | 0.0038 | 0.0037 | 0.0036 |
| 2.7 | 0.0035 | 0.0034 | 0.0033 | 0.0032 | 0.0031 | 0.0030 | 0.0029 | 0.0028 | 0.0027 | 0.0026 |
| 2.8 | 0.0026 | 0.0025 | 0.0024 | 0.0023 | 0.0023 | 0.0022 | 0.0021 | 0.0021 | 0.0020 | 0.0019 |
| 2.9 | 0.0019 | 0.0018 | 0.0018 | 0.0017 | 0.0016 | 0.0016 | 0.0015 | 0.0015 | 0.0014 | 0.0014 |
| 3.0 | 0.0014 | 0.0013 | 0.0013 | 0.0012 | 0.0012 | 0.0011 | 0.0011 | 0.0011 | 0.0010 | 0.0010 |
| 3.1 | 0.0010 | 0.0009 | 0.0009 | 0.0009 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0007 | 0.0007 |
| 3.2 | 0.0007 | 0.0007 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0005 | 0.0005 | 0.0005 |
| 3.3 | 0.0005 | 0.0005 | 0.0005 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0003 |
| 3.4 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0002 |

| $Q(a)$ | $a$ |
|---|---|
| $10^{-4}$ | 3.73 |
| $5 \times 10^{-5}$ | 3.90 |
| $10^{-5}$ | 4.27 |
| $5 \times 10^{-6}$ | 4.43 |

| $Q(a)$ | $a$ |
|---|---|
| $10^{-6}$ | 4.76 |
| $10^{-7}$ | 5.20 |
| $10^{-8}$ | 5.61 |
| $10^{-9}$ | 6.00 |

# Appendix II

## Probability of Call Blocking in an Erlang B System


Number of Trunked Channels (C)
2 3 4 5 6 7 8 9 10 12 14 16 18 20 25 30 35 40 45 50 60 70 80 90 100
Probability of Blocking
Traffic Intensity in Erlangs